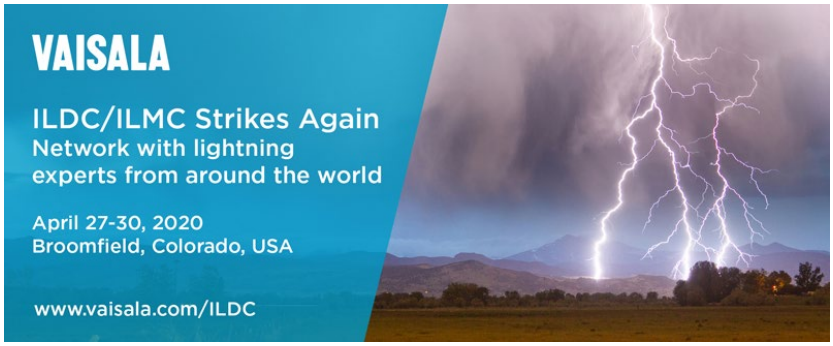


# Terrestrial Gamma-Ray Flashes and Energetic Intra-Cloud Lightning in Northeast Colorado

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## Abstract

While the exact conditions responsible for the runaway electron avalanche that produce terrestrial gamma ray flashes (TGFs) remain unknown, they are associated with energetic intra-cloud (IC) lightning and studying both phenomena together may provide key details behind their shared occurrence context. TGFs, one of the most energetic natural photon emissions on Earth, are associated with thunderstorms and may pose a significant radiation exposure to humans near a TGF source. With an increasing knowledge of the occurrence context of distinct types of lightning within storms, lightning remote sensing may elucidate the kinematic and microphysical environment of TGF production. In particular, distinct energetic intra-cloud (IC) lightning discharges, such as compact intra-cloud lightning discharges (CIDs) and energetic intra-cloud pulses (EIPs), are strong candidates for thunderstorm remote sensing research, since both are observable by radio instruments on the ground, they occur in different thunderstorm environments, and ±EIPs have been linked to TGFs [*Lyu et al.*, 2015, XX].

Understanding the production environment shared by thunderstorm lightning and TGFs will also help reveal the mechanisms behind other associated phenomena, such as thunderstorm severe weather, which poses a significant danger to public safety and property by way of intense lightning, large hail, heavy precipitation, strong winds, or tornadoes. In this study, lightning radio observations ("sferics") of energetic intra-cloud lightning coupled with TGF observations are used to address these questions: (a) Are all TGFs associated with a lightning sferic observable on the ground? (b) What is the distribution of TGFs associated with the different types of lightning phenomena?

The lightning sferics were observed by a deployed array of three Low-Frequency (LF) radio receivers in northeastern Colorado between July and September of 2019. The TGF events were observed by the Atmosphere-Space Interactions Monitor (ASIM), installed on the International Space Station, which was triggered 594 times during the period and region corresponding to the sferic dataset. Using magnetic direction finding and time of arrival for each observed lightning event at different LF stations, the source location is estimated using a statistical least squares filter, along with clock errors associated with the receivers.

The sferic amplitude at the source, a proxy for peak current, is computed using an atmospheric attenuation inverse model. The energetic lightning events in the campaign are then classified automatically between cloud-to-ground (CG), IC, CID or EIP, following the parameterization scheme suggested by *Lyu et al.*, [2015]. The classified energetic ICs and TGF events are then paired together based on an unambiguous timing tolerance. With the paired dataset of ICs and TGFs, a statistical analysis and an in-depth study of a few individual TGF cases is performed. The statistical analysis will also be augmented by the use of derived science products from the geostationary lightning mapper (GLM) instrument onboard the GOES-East satellite, to help quantify the observability of TGF events from satellite-based lightning detection.

## Topic Areas

Lightning Physics, Characteristics and Measurements

## Submission Format

No preference